

02 MAR 2005

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property
Organization
International Bureau



(43) International Publication Date
18 March 2004 (18.03.2004)

PCT

(10) International Publication Number
WO 2004/022856 A1

(51) International Patent Classification⁷: E02B 9/08
(21) International Application Number:
PCT/GB2003/003845

(22) International Filing Date:
5 September 2003 (05.09.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0220626.6 5 September 2002 (05.09.2002) GB

(71) Applicant (for all designated States except US): ROBERT
GORDON UNIVERSITY [GB/GB]; Schoolhill, Aber-
denn AB10 1FR (GB).

(72) Inventors; and

(75) Inventors/Applicants (for US only): OWEN, Alan
[GB/GB]; Braeside Schoolhouse, Auchnagatt, Ellon
AB41 8YE (GB). BRYDEN, Ian, Gordon [GB/GB]; 62
Brentfield Circle, Ellon, Aberdeenshire AB41 9DD (GB).

(74) Agent: MURGITROYD & COMPANY; Scotland
House, 165-169 Scotland Street, Glasgow G5 8PL (GB).

(81) Designated States (national): AE, AG, AL, AM, AT, AU,
AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU,
CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH,
GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC,
LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW,
MX, MZ, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC,
SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA,
UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

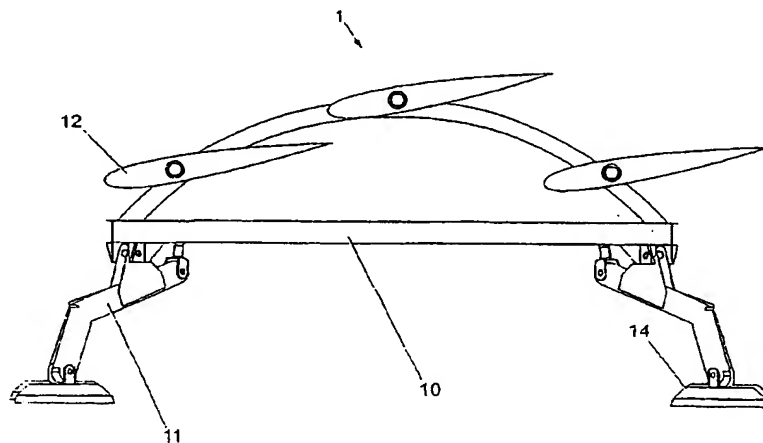
(84) Designated States (regional): ARIPO patent (GH, GM,
KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW),
Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),
European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE,
ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO,
SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM,
GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

- with international search report
- before the expiration of the time limit for amending the
claims and to be republished in the event of receipt of
amendments

For two-letter codes and other abbreviations, refer to the "Guid-
ance Notes on Codes and Abbreviations" appearing at the begin-
ning of each regular issue of the PCT Gazette.

(54) Title: APPARATUS FOR CONTROLLING UNDERWATER BASED EQUIPMENT



(57) Abstract: The apparatus may include a space frame (10, 110) on which is mounted at least one hydrofoil (12, 112) for generating positive or negative lift. The frame (10, 110) is attachable to underwater equipment such as a turbine. The hydrofoils (12, 112) are adapted to produce negative lift when a flow of liquid passes over them and so in use cause the apparatus (10, 110) and attached equipment to sink to the seabed. The flow of water over the hydrofoils continue to produce negative lift and so maintain the apparatus (1, 100) on the seabed. In certain embodiments, the hydrofoils (12) can typically be set to a passive configuration in which they flip over when the current flow changes direction. Furthermore, the hydrofoils (12) are selectively rotatable to provide an angle of attack such that they may be adapted to provide positive lift when it is necessary to remove the apparatus (1) from the water.

WO 2004/022856 A1

10/526264

WO 2004/022856

8/p1TS

DT06 Rec'd PCT/PTO 0 2 MAR 2005
PCT/GB2003/003845

1 "Apparatus for Controlling Underwater Based
2 Equipment"

3
4 Technical field

5
6 The invention relates to an underwater location
7 device such as may be used for controlling the
8 launch, positioning or recovery of a tidal turbine
9 or other underwater equipment. It should be noted
10 that the example of a tidal turbine is used herein
11 but the invention is not limited to such uses.

12
13 Background art

14
15 Tidal currents offer a considerable source of
16 sustainable energy at various sites throughout the
17 world, usually within easy reach of land and in
18 relatively shallow waters. Tidal currents are
19 created by movement of the tides around the earth
20 producing a varying sea level, dependent on the
21 phases of the moon and sun. As the sea levels vary,
22 so the waters attempt to maintain equilibrium.

WO 2004/022856

PCT/GB2003/003845

2

1 subject to gravitational forces, thus inducing flow
2 from one area of sea to another. This flow is
3 modified by a number of factors such as, the
4 Coriolis forces due to the earth rotation,
5 earth/moon/sun alignment, local topography,
6 atmospheric pressure and temperature and salinity
7 gradients. The major advantage of tidal power
8 generation is its regularity, which can be predicted
9 for years in advance.

10

11 According to a study by the ETSU (Energy Technology
12 Support Unit) the United Kingdom may obtain up to 20
13 percent of its total electricity by using these
14 systems to collect energy from fast moving tidal
15 currents that exist in channels and offshore areas.
16 Similar resources have been noted to exist elsewhere
17 such as in the Straits of Messina, between Sicily
18 and mainland Italy.

19

20 The most powerful flows tend to occur in areas of
21 restriction, either by width or depth, but for the
22 same reasons are not suitable for widespread
23 exploitation by large, fixed devices which require a
24 minimum rotor area, and therefore water depth, to
25 justify the costs of installation and maintenance.
26 It is assumed from the outset that new tidal barrage
27 systems are unlikely ever to be pursued due to their
28 inherent properties of high cost, delayed financial
29 return, and serious environmental consequences.

30

31 The considerable size of the available resource has
32 attracted various proposals for its exploitation.

WO 2004/022850

PCT/GB2003/003845

3

1 The following represents the existing systems within
2 the field of tidal current energy extraction. It is
3 assumed that power transmission problems will be
4 equal for any system, and that all systems will
5 require some form of non-toxic anti-fouling agent.

6
7 There also exist operational environmental impacts
8 common to all methods of tidal power generation,
9 such as, an inherent risk of collision damage to
10 fish and marine mammals, redirection of currents and
11 the sediments and food particles contained within
12 them, and shipping, particularly fishing.

13
14 A first type of tidal current energy extraction
15 system encountered on the market is the Monopile
16 system. This technology is well known and
17 understood by contractors familiar with the offshore
18 oil industry. It consists of twin axial flow
19 turbines, each turbine driving a generator via a
20 gearbox, mounted on streamlined cantilevers either
21 side of a circular section, vertical steel monopile.
22 It is anticipated that a number of structures will
23 be grouped together in 'farms'. The planning of
24 such a tidal 'farm' would need to be accurately
25 modelled for wake effects, as once installed, the
26 monopile is expensive to re-site. In addition,
27 operational depth is restricted to the 20m - 35m
28 range. Concerning the installation and maintenance,
29 monopile systems require a hole to be drilled in
30 suitable bedrock and the base of the turbine tower
31 is secured within the socket so produced. Existing
32 monopile support mechanisms for presenting a tidal

WO 2004/022856

PCT/GB2003/003845

4

1 turbine to the tidal currents are expensive, thus
2 making only a few sites economically viable for
3 power generation and requiring considerable sub sea
4 engineering expertise.

5
6 The current monopile systems permit raising the
7 turbines above water level for maintenance and
8 repair, which is beneficial, but the long-term (i.e.
9 20 years) reliability and corrosion resistance of
10 the necessary mechanism must be questionable. The
11 protrusion of the piles above sea level would reduce
12 the likelihood of impact with passing vessels.

13
14 Concerning the environmental and decommissioning
15 issues, the impact of installation would be
16 considerable, especially to the benthic flora and
17 fauna, but subsequently the piles may become areas
18 of shelter and therefore, populated. To minimise
19 the danger to shipping and fishing, decommissioning
20 would require complete removal of the piles, which
21 would disturb the benthic population once again.

22
23 A second type of tidal current energy extraction
24 system that exists in the prior art is the floating
25 tether. This floating tether device is anchored to
26 the seabed with a mooring cable and suspended clear
27 of the seabed using a flotation buoy. The axial
28 flow tidal current turbine is free to position
29 itself into the direction of the tidal flow, which
30 obviates the need for a yaw mechanism.

31

WO 2004/022856

PCT/GB2003/003845

5

1 Several prototypes have already been developed
2 including a 10-kilowatt device tested in Scotland in
3 1994. At present, the arrangement is unlikely to be
4 suitable for large power output installations due to
5 the relative sizes of anchor, turbine and float. On
6 occasions of relatively high velocity tidal streams
7 (e.g. spring tides), if the anchor holds, the
8 turbine will be dragged lower in the water with the
9 unwanted potential to collide with the seabed.
10
11 Concerning the installation of the floating tether
12 system, it is relatively quick and inexpensive.
13 However, visual inspection would need to be frequent
14 as the structure is likely to be subject to storm
15 damage and fatigue loading of the cable, leading to
16 possible loss of the supporting float and subsequent
17 sinking of the device, or loss of anchorage and
18 subsequent drifting. Once sunk, the device would be
19 open to damage by the oscillating tidal currents and
20 could prove difficult to recover, whilst a drifting
21 device would potentially cause damage to any other
22 moored turbines in its path.
23
24 Due to the length of tether required and the random
25 positioning of the device at any one time, this
26 arrangement is not suitable for closely grouped
27 tidal farms and a safe spread would fail to make
28 economical use of the power available in a given
29 area. For the same reasons, this type of
30 arrangement would present a hazard to all forms of
31 shipping, large and small. It would, however
32 present a possible solution to a one-off, small

WO 2004/022856

PCT/GB2003/003845

6

1 scale installation in areas such as the mouth of a
2 sea loch. Concerning the environmental impacts of
3 installation and decommissioning of the floating
4 tether systems, it will be minimal, leaving no
5 footprint on removal.

6

7 A third type of tidal current energy extraction
8 system that also exists in the prior art is the
9 oscillating hydroplane system. In that system, a
10 central post mounted on five legs supports a complex
11 mechanism comprising two interconnected symmetrical
12 hydrofoils. These hydrofoils are used to pump high-
13 pressure oil, which drives an electrical generator
14 via a hydraulic motor. At the end of each stroke,
15 the hydrofoils are tilted to give the required angle
16 of attack to produce the return stroke, thus
17 creating an oscillating motion.

18

19 Concerning the installation and maintenance, at
20 present, the oscillating hydroplane system does not
21 yet possess a launch and recovery mechanism. As a
22 result of the constant oscillations and considerable
23 number of moving parts, it is probable that this
24 device will be subject to high dynamic loading and
25 subsequent fatigue stress. The upward stroke of the
26 hydrofoils will tend to lift the device off the
27 seabed and hence increase the possibility of it
28 being washed away at high tidal stream velocities.

29

30 Concerning the environmental impacts of installation
31 and decommissioning of the oscillating hydroplane
32 systems, they are expected to be minimal, leaving no

WO 2004/022856

PCT/GB2003/003845

7

1 footprint on removal. However, this cannot be
2 confirmed until a launch/recovery mechanism is
3 proposed. Using high pressure oil as a means of
4 power transmission does however introduce the
5 possibility of pollution in the event of leakage.

6

7 Some 'tidal' energy extraction systems can also be
8 used in freshwater applications such as rivers.

9

10 With these existing systems and designs, it is a
11 problem that their instabilities during operations
12 as well as during launch and recovery, if possible,
13 might cause damage. In addition, since these
14 systems are becoming larger and larger, the frequent
15 installation and maintenance operations will become
16 more and more difficult and expensive.

17

18 Summary of the invention

19

20 It is an object of the present invention to obviate
21 or mitigate the problems of controlling underwater
22 equipment in a flowstream.

23

24 In a first aspect, the invention described herein
25 relates to an apparatus for controlling underwater
26 equipment comprising:

27 attachment means for attaching underwater

28 equipment to the apparatus; and

29 at least one member for generating positive or
30 negative lift.

31

WO 2004/022856

PCT/GB2003/003845

8

1 Preferably, the at least one member is adapted to
2 create a negative lift due to fluid flow in a first
3 direction and is adapted to create a negative lift
4 due to fluid flow in a second, different, direction.
5

6 Preferably, the first and second directions are
7 generally opposite to each other.
8

9 Preferably, the apparatus is adapted to anchor the
10 underwater equipment to a sea- or river-bed.
11

12 Preferably, the attachment means is adapted to
13 attach the underwater equipment in close proximity
14 to the centre of gravity of the apparatus.
15

16 Preferably, the space frame is mounted on a number
17 of feet equipped with slippage prevention means,
18 which may be an arrangement of spikes or the like,
19 to typically resist slipping by shear force rather
20 than relying on friction alone such that, in use,
21 the negative lift will preferably tend to force said
22 slippage prevention means into a sea- or river-bed
23 thus resisting the drag forces acting on the space
24 frame tangentially to the seabed.
25

26 Preferably, the at least one member comprises at
27 least one hydrofoil.
28

29 Typically, differences in pressure acting on
30 opposing surfaces of each of the at least one member
31 due to a predetermined angle of attack causes said

WO 2004/022856

PCT/GB2003/003845

9

1 at least one member to generate negative or positive
2 lift.

3

4 Preferably, the apparatus is adapted to control the
5 launch and/or recovery of the underwater equipment
6 attached to it.

7

8 In a preferred embodiment, the at least one members
9 are rotatable to any position and even more
10 preferably in the region of 160° to 200° about a
11 longitudinal axis of the respective member.

12

13 Preferably, the hydrofoils are symmetrical.

14

15 Said at least one members preferably comprise at
16 least one hydrofoils which are more preferably self-
17 rectifying static hydrofoils, which may be capable
18 of passive rotation about an axis such that each
19 hydrofoil maintains alignment with a periodically
20 reciprocating rectilinear flow.

21

22 Moreover, the at least one members are preferably
23 moveable between a first configuration in which they
24 are capable of generating positive lift and a second
25 configuration in which they are capable of
26 generating negative lift.

27

28 Preferably, the at least one member has a variable
29 actuating means to vary the positive or negative
30 lift generated by the member.

31

WO 2004/022856

PCT/GB2003/003845

10

1 Preferably, said actuating means comprises a motor
2 which may be a hydraulic, pneumatic or electric
3 actuated motor. Preferably, a shaft member is
4 actuated when a change between first and second
5 configurations is required, said actuation typically
6 causing the shaft member to rotate through a
7 predetermined angle, which may be in the region of
8 180°.

9
10 Preferably, said apparatus comprises a support
11 framework which is typically composed of sub
12 frameworks, where a number of shaft members are
13 connected to the framework and on which said
14 symmetrical hydrofoils are coupled. Preferably, the
15 at least one hydrofoils are coupled to the support
16 framework by a respective bearing member connected
17 to the hydrofoil. The bearing member of the
18 hydrofoil is typically coupled to the shaft member
19 of the framework, the bearing member and shaft
20 member combining to provide a rotation enabling
21 portion and a rotation prevention portion.
22 Preferably, the bearing member is substantially
23 cylindrical. The rotation prevention portion
24 typically comprises at least one stop members (which
25 may be in the form of lugs mounted on the shaft
26 member) and which are adapted to engage with at
27 least one respective stop members (which may also be
28 lugs) mounted on the respective bearing member of
29 each hydrofoil. Typically, the bearing member
30 comprises a pair of stop members which are spaced
31 apart around its inner circumference, typically
32 being spaced apart by approximately 180°.

WO 2004/022856

PCT/GB2003/003845

11

1 Typically, the shaft member comprises a pair of stop
2 members which are spaced apart around its outer
3 circumference, typically being spaced apart by
4 approximately 180°. Preferably, one of the bearing
5 stop members is engageable with a respective shaft
6 stop member to define the first negative
7 configuration and the other of the bearing stop
8 members is engageable with the other of the shaft
9 stop members to define the second negative
10 configuration.

11

12 Preferably, said apparatus is a multi-legged, self-
13 levelling space frame equipped with a plurality of
14 hydrofoils, typically at different heights.

15

16 In alternative embodiments, the at least one member
17 is rigidly connected to a support framework and is
18 unsymmetrical. Preferably, the at least one member
19 comprises a disc shaped member which, in use, is
20 adapted to produce positive or negative lift
21 regardless of the direction of flow of fluid
22 thereby. Preferably, the disc shaped member
23 produces negative lift.

24

25 According to a second aspect of the invention, there
26 is provided a method of controlling underwater
27 equipment; the method comprising:

28 providing an apparatus having at least one
29 member for generating positive or negative lift;
30 attaching the apparatus to underwater
31 equipment;
32 releasing the apparatus into a fluid;

WO 2004/022856

PCT/GB2003/003845

12

1 allowing fluid to flow past the at least one
2 member to generate positive or negative lift.

3

4 Preferably, the method according to the second
5 aspect of the invention is performed using the
6 apparatus according to the first aspect of the
7 invention.

8

9 Preferably, the apparatus is placed in a flow of
10 water.

11

12 Preferably, the underwater equipment is a turbine.

13

14 According to a further aspect of the present
15 invention, there is provided an apparatus for
16 maintaining underwater equipment within a sea or
17 river tidal current location, the apparatus
18 comprising at least one moveable members capable of
19 generating negative lift, where said at least one
20 members are moveable between a first configuration
21 in which they create a negative lift due to flow in
22 a first direction, and a second configuration in
23 which they create a negative lift due to flow in a
24 second, different, direction.

25

26 The invention also provides energy extracting
27 apparatus for extracting energy from fluid flow,
28 said energy extracting apparatus comprising:

29 a turbine;

30 at least one member, which in use, generates
31 positive or negative lift.

WO 2004/022856

PCT/GB2003/003845

13

1

2 Brief description of the drawings

3

4 Embodiments of the present invention will now be
5 described, by way of example only, with reference to
6 the accompanying drawings, in which:-

7

8 Figure 1 shows a side view of a space frame in
9 accordance with the present invention, showing
10 a tubular frame allowing the positioning of the
11 hydrofoils at differing heights;

12 Figures 2a to 2d show the passive reversing of
13 the hydrofoils in response to a change in flow
14 direction whilst Figures 2e to 2h show the
15 different movements of hydrofoils of Figure 1
16 actuated by hydraulic motors to create positive
17 and negative lifts during launch, recovery and
18 transitional operations according to the
19 present invention;

20 Figures 2i to 2m show the passive reversing of
21 the hydrofoils in response to a change in flow
22 direction;

23 Figure 3 in its upper half shows a first side
24 view, and in its lower half shows an opposite
25 side view, illustrating the fundamental
26 geometry of the passive reversing mechanism;

27 Figure 3a in its upper half shows a first side
28 view, and in its lower half shows an opposite
29 side view, illustrating the fundamental
30 geometry of the passive reversing mechanism;

WO 2004/022856

PCT/GB2003/003845

14

1 Figure 3b is a third side view showing the
2 fundamental geometry of the passive reversing
3 mechanism;
4 Figure 4 shows in detail the assemblage of
5 hydrofoils onto the space frame of Figure 1;
6 Fig. 5a is a side view of a second embodiment
7 of an apparatus in accordance with the present
8 invention and an attached canister;
9 Fig. 5b is a front view of the Fig. 5a
10 apparatus with the attached canister;
11 Fig. 5c is a plan view of the Fig. 5a apparatus
12 with the attached canister; and,
13 Figs. 5d-5f are a series of views of an
14 attachment ring which forms part of the Fig. 5a
15 apparatus.

17 Detailed description of the invention

18
19 According to the present invention, the apparatus
20 for launching an underwater device from a vessel,
21 securing the underwater device whilst in operation
22 on the seabed and permitting recovery to a vessel,
23 for maintenance and repair should be as simple as
24 possible without involving any sophisticated and
25 specialised equipment. A first embodiment of the
26 invention is shown in Figure 1 and utilises passive,
27 self-rectifying static hydrofoils, the central shaft
28 (see Figure 3) of which can be rotated through 180°
29 to generate positive or negative lift as required.

30
31 As is shown in Figure 1, the apparatus 1 for
32 controlling the launch, secure positioning and

WO 2004/022856

PCT/GB2003/003845

15

1 recovery of an underwater device comprises a space
2 frame 10 for attaching to any desired underwater
3 device such as power extraction equipment which may
4 comprise a tidal turbine (not shown), a hydrofoil
5 support frame to accommodate the self rectifying
6 hydrofoil mechanisms 12 and hydraulically operated
7 legs 11 for levelling of the apparatus 1. The feet
8 14 are equipped with spikes or similar serrated
9 attachments (not shown) to initiate grip on the sea
10 or river bed.

11
12 The hydrofoils 12 are inclined in such a way as to
13 generate a significant downforce as a result of the
14 stream flow over their surfaces. This downforce
15 will push the apparatus 1 into the seabed, and,
16 since the actual applied force will be proportional
17 to the square of the velocity of the fluid passing
18 over them, the apparatus 1 will be more securely
19 fixed as the streamflow velocity increases. By this
20 means the apparatus can overcome overturning moments
21 applied to the underwater device that it supports.

22
23 The space frame 10 is shown as arched tubing but is
24 not restricted to shape since any frame
25 configuration offering different levels of mounting
26 point for the hydrofoils 12 will suffice. The
27 apparatus 1 as shown has multiple hydrofoils 12 but
28 any number of hydrofoils 12 will suffice. As is
29 shown in Figures 2a to 2h, each hydrofoil 12 is
30 mounted on a central shaft 48 such that it may
31 rotate upwards from horizontal (or any angle of
32 inclination above horizontal) through vertical to

WO 2004/022856

PCT/GB2003/003845

16

1 any angle above horizontal but now pointing in the
2 opposite direction. The angle of attack of the
3 hydrofoils 12 is governed by the relative size and
4 positioning of lugs 46 attached to the central shaft
5 48 and the corresponding lobes 44 attached to an
6 outer shaft (not shown) which is itself fixed to the
7 hydrofoil 12.

8
9 In a preferred embodiment, the apparatus 1 according
10 to the present invention comprises a multi-legged,
11 self-levelling space frame 10 equipped with a number
12 of hydrofoils 12 at different heights with any
13 underwater device, such as a tidal turbine, it
14 supports, situated as close as practicable to the
15 centre of gravity of the apparatus 1.

16
17 It is anticipated that the space frame 10 will be
18 mounted on a number of feet 14 equipped with spikes
19 (not shown) to resist slipping of the apparatus 1
20 with respect to the river bed (not shown) by shear
21 force rather than relying on friction alone. The
22 number of feet 14A, 14B required will depend on the
23 weight of the apparatus 1; however, the location and
24 the shape of these supporting feet 14A, 14B aim at
25 holding the apparatus 1 in the orientation shown in
26 Figure 1 upwards against the current and thus
27 ensuring the stability of the space frame 10. The
28 negative lift (arrow A) will tend to force these
29 spikes into the sea or river bed (not shown in
30 Figure 1) thus resisting the drag forces acting on
31 the space frame 10 tangentially to the sea or river
32 bed.

WO 2004/022856

PCT/GB2003/003845

17

1
2 The drag forces acting on the underwater device
3 (such as the tidal turbine) attached to the
4 apparatus 1 will naturally tend to apply an
5 overturning moment to the space frame 10 about its
6 rearmost feet 14B, with respect to the direction of
7 flow (arrow F). These forces will however be
8 overcome by positioning the hydrofoils 12 at
9 stations such that the negative lift (arrow A),
10 created by the foremost or upstream (those at the
11 left hand side of the space frame 10 as shown in
12 Figure 1) hydrofoils 12 acting over the length of
13 the space frame 10, is arranged to exceed the
14 overturning moment.

15
16 Thus, the space frame 10 is symmetrical about its
17 midpoint M with the hydrofoils 12 being coupled to
18 the space frame 10 in a manner, to be subsequently
19 detailed in a discussion of Figures 2a to 2h, which
20 allows them to passively reverse with stream flow F
21 to maintain compressive forces in a downwards
22 direction A and restraining moments regardless of
23 tidal stream direction.

24
25 During operation of the apparatus 1, the hydrofoils
26 12 are free to rotate (shown as clockwise in Figures
27 2a to 2d and 2I to 2m) in response to the change in
28 tidal stream flow F direction in a manner which is
29 shown from left to right in Figures 2a to 2d to
30 create a negative lift (arrow A) so as to push the
31 apparatus 1 into the seabed.

32

WO 2004/022856

PCT/GB2003/003845

18

1 When the apparatus 1 is to be installed on the
2 seabed or is to be recovered from the seabed for
3 e.g. maintenance of the apparatus 1, as shown in the
4 Figures 2a to 2d, hydraulic motors 30, via a
5 suitable gearing mechanism such as a worm and wheel
6 arrangement 32 (as shown in Figure 3) or chain type
7 mechanism (not shown), are utilised to rotate (shown
8 as anticlockwise in Figures 2e to 2h) the
9 longitudinal axes (i.e. the horizontal axes
10 perpendicular to the stream flow 12) of the
11 hydrofoils 12 through the required angle until the
12 hydrofoils 12 have reached the configuration shown
13 Figure 2h; for the configuration shown in Figures 2e
14 to 2h, this angle is approximately 180°. It should
15 be kept in mind that the hydraulic motors 30 can be
16 replaced by pneumatic or electric motors. In other
17 words, if the apparatus 1 is towed, e.g. by a boat
18 or other vessel or installation at the surface, the
19 hydrofoils 12 will produce positive lift (arrow B)
20 as shown in Figures 2e to 2h. For launch and
21 recovery, this positive lift can be utilised to
22 raise or lower the space frame 10 within the tidal
23 stream. If required, this action could be augmented
24 by forming air tanks within the space frame 10 that
25 can be 'blown' with compressed air to improve the
26 buoyancy of the apparatus 1. If the hydraulic
27 motors 30 use the worm and wheel mechanism 32 form
28 of drive, the hydrofoil 12 positions can be altered
29 over a range of positions, thus permitting the
30 apparatus 1 to be 'flown' in the water. Hydraulic
31 connections (and pneumatic connections if required)

WO 2004/022856

PCT/GB2003/003845

19

1 can be affixed to a supporting marker buoy (not
2 shown) for ease of access.

3

4 Figure 3 shows the mechanism and assemblage of
5 hydrofoils 12, hydraulic motors 30 and worm and
6 wheel drive shaft mechanisms 32 in more detail. The
7 hydrofoils 12 are free to rotate about a central
8 shaft 48, through an included angle of say 160°
9 which will maintain an angle of 10° to the
10 horizontal. The 10° angle effectively becomes an
11 angle of attack when the tidal stream flow F
12 reverses. Thus as the tidal stream 10 reciprocates,
13 the hydrofoils 12 will maintain an angle of 10° ,
14 creating a negative lift (arrow A), which will
15 therefore push the spikes 16 into the seabed and
16 immobilise the space frame 10. As will be described
17 subsequently, positioning lugs 46 mounted on a
18 central shaft 48 provided a stop for locating lobes
19 44 of the hydrofoil 12, such that the hydrofoil 12
20 cannot rotate further than the 160° shown in Figures
21 2a to 2d.

22

23 By rotating the central shaft 48 through slightly
24 greater than 180° (say 200°), the negative lift
25 becomes positive lift (arrow B) and the space frame
26 10 will rise through the water so that the tidal
27 turbine 90 can be recovered on the vessel (not
28 shown).

29

30 Figure 4 shows in more detail the mechanical
31 assemblage of hydrofoils 12 with space frame 10.
32 The hydraulic motor 30 for actuating the positioning

WO 2004/022856

PCT/GB2003/003845

20

1 gear is equipped with a drive shaft 32 that is
2 utilised for rotating an indented positioning gear
3 42 or a toothed gear wheel. The positioning gear 42
4 is solidly attached to a central shaft 48 which
5 passes through a bore provided in the larger end of
6 each hydrofoil 12, a section of which is show on
7 Figure 4. The bore of the hydrofoil 12 is provided
8 with a pair of diametrically opposed and inwardly
9 projecting hydrofoil locating lobes 44. The central
10 shaft 48 has a pair of diametrically opposed and
11 outwardly projecting positioning lugs 46, each one
12 of which selectively co-operates with one of the
13 respective pair of diametrically opposed hydrofoil
14 locating lobes 44.

15
16 Thus, by rotating the drive shaft 32, the hydraulic
17 motor 30 actuates or rotates the position gear 42
18 which in turn rotates the central shaft 48. The
19 positioning lugs 46 will contact the locating lobes
20 44 and carry them 44 (and the hydrofoil 12) about
21 the rotational axis of the central shaft 48 until
22 the hydrofoil 12 is in the desired configuration,
23 this being through an angle of approximately 160°
24 until the hydrofoil 12 is in the configuration shown
25 in Figure 2h. At this point, the motor 30 is de-
26 actuated and the positioning lugs 46 will hold the
27 hydrofoil 12 locked in this configuration. The
28 rotation of 160° enables the hydrofoil 12 to
29 maintain an angle of 10° to the horizontal in order
30 to provide an angle of attack when the tidal stream
31 F reverses.

32

WO 2004/022856

PCT/GB2003/003845

21

1 Conversely, the rotation of the central shaft 48 by
2 180° drives the hydrofoils 12 to create a positive
3 lift and in which case, the space frame 10 will rise
4 through water. Figure 3a shows how the attitude of
5 the hydrofoil 12 is changed by a simple 180°
6 clockwise rotation of the central shaft 48.

7
8 The apparatus according to the present invention,
9 can be launched and recovered by a non-specialist
10 vessel, using non-specialist equipment. Indeed if
11 the vessel is large enough, a number of apparatus 1
12 may be launched or recovered in a day without the
13 need to return to port. This will also permit easy
14 access for maintenance and repair. Since apparatus
15 1 possesses few moving parts and no complex
16 mechanisms, it should be inherently reliable.

17
18 A second embodiment of an apparatus in accordance
19 with the present invention is shown in Figs. 5a-5d.
20 The apparatus 100 comprises a tripod support frame
21 110, a bottom ring or stand 126, a disc-shaped
22 hydrofoil 112, support brackets 120 and an
23 attachment ring 122 with bolts 123. The apparatus
24 100 is attached to an ADCP canister 124 via the
25 attachment ring 122 and bolts 123. Other subsea
26 equipment may also be attached to the apparatus 100
27 in place of the canister 124.

28
29 The hydrofoil 112 is rigidly connected to the frame
30 110 via the support brackets 120 and its plane is
31 generally parallel to the main plane defined by the
32 bottom ring 126 such that the hydrofoil 122 will be

WO 2004/022856

PCT/GB2003/003845

22

1 generally parallel to the seabed in use. A central
2 aperture 119 is provided within the hydrofoil 112.
3 A lower face 113 of the hydrofoil 112 faces the
4 stand 126 and is of a generally flat surface,
5 whereas its opposite, upper, face 115 faces away
6 from the stand 126 and gradually curves upwards away
7 from the main plane of the hydrofoil as it
8 approaches the central aperture 119 to form a raised
9 lip portion 117. This can be achieved by the
10 assembly of a plurality of smaller hydrofoils 112s
11 to produce a multi-faceted hydrofoil 112. The
12 hydrofoil 112 thus has rotational symmetry around a
13 central axis 118 but is not symmetrical on either
14 side of its main plane.

15

16 Thus when a flow of water passes over each face 113,
17 115 of the hydrofoil 112, the reaction force of the
18 water on the raised lip 117 pushes the hydrofoil 112
19 along with the other components of the apparatus 100
20 and ADCP canister 124 in a downwards direction -
21 that is "negative lift" results.

22

23 Thus in use, the hydrofoil helps to direct the
24 apparatus 100 and attached equipment towards the
25 seabed and once in position, the hydrofoil maintains
26 the apparatus and equipment on the seabed.

27

28 The apparatus 100 may be attached to a line (not
29 shown) and the line attached at its other end to a
30 buoy. If the apparatus needs to be recovered, the
31 apparatus may be pulled in by the line.

32

WO 2004/022856

PCT/GB2003/003845

23

1 An advantage of certain embodiments of the present
2 invention, such as the second embodiment, is that
3 they continue to perform their function of providing
4 negative lift regardless of the direction of flow of
5 the water.

6

7 An advantage of the second embodiment of the
8 invention is that it includes no moving parts and so
9 is reliable and requires minimal maintenance.

10

11 The embodiments described herein may also be
12 provided with an integral turbine or other
13 underwater equipment rather than attaching such
14 equipment to the apparatus before use.

15

16 Although reference is made to employing the
17 apparatus 1, 100 in a tidal current and in certain
18 embodiments using a tidal turbine, it is to be
19 understood that the apparatus 1, 100 may be placed
20 in any flow of liquid such as rivers and are not
21 limited to their use tidal areas.

22

23 An advantage of certain embodiments of the present
24 invention is that they permit the launch and
25 recovery of underwater equipment to be carried out
26 using a non-specialist but suitably equipped vessel.

27

28 Concerning the primary environmental impact of
29 embodiments of apparatus 1 according to the present
30 invention, it would have some impact upon the
31 benthic flora and fauna, and, although the
32 positioning and retrieval of apparatus 1 would be

WO 2004/022856

PCT/GB2003/003845

24

1 relatively frequent (at least once every year is
2 anticipated), nothing more than temporary localised
3 disturbance is anticipated. There exists some
4 potential for hydraulic oil leakage, but the system
5 contents are minimal so, even in the event of
6 complete system evacuation, any oil contamination
7 would be minor. Operational environmental hazards
8 are in common with the other forms of tidal energy
9 extraction and decommissioning would leave no
10 footprint.

11
12 Improvements and modifications in terms of
13 dimensions and locations of the different parts
14 described above may be incorporated to the
15 hereinbefore described apparatus for controlling the
16 launch and recovery of a tidal turbine without
17 departing from the scope of the present invention.

WO 2004/022856

PCT/GB2003/003845

25

1 CLAIMS:-

2

3 1. Apparatus for controlling underwater equipment
4 comprising:

5 attachment means for attaching underwater

6 equipment to the apparatus; and

7 at least one member for generating positive or
8 negative lift.

9

10 2. Apparatus according to claim 1, wherein the at
11 least one member is adapted to create a negative
12 lift due to fluid flow in a first direction and is
13 adapted to create a negative lift due to fluid flow
14 in a second, different, direction.

15

16 3. Apparatus as claimed in claim 2, wherein the
17 first and second directions are generally opposite
18 to each other.

19

20 4. Apparatus as claimed in any preceding claim,
21 which, in use, is adapted to anchor the underwater
22 equipment to a sea- or river-bed.

23

24 5. Apparatus according to any preceding claim,
25 wherein the attachment means is adapted to attach
26 the underwater equipment in close proximity to the
27 centre of gravity of the apparatus.

28

29 6. Apparatus according to any preceding claim,
30 wherein the apparatus is mounted on a number of feet
31 equipped with slippage prevention means, to resist
32 slipping by shear force such that, in use, the

WO 2004/022856

PCT/GB2003/003845

26

1 negative lift will preferably tend to force said
2 slippage prevention means into a sea- or river-bed
3 thus resisting the drag forces acting on the
4 apparatus tangentially to the seabed.

5

6 7. Apparatus as claimed in any preceding claim,
7 wherein the at least one member comprises at least
8 one hydrofoil.

9

10 8. Apparatus according to any preceding claim,
11 wherein differences in pressure acting on opposing
12 surfaces of the at least one member due to a
13 predetermined angle of attack causes said at least
14 one member to generate negative or positive lift.

15

16 9. Apparatus as claimed in any preceding claim,
17 which is adapted to control the launch and/or
18 recovery of the underwater equipment.

19

20 10. Apparatus according to any preceding claim,
21 wherein the at least one member is free to rotate
22 through a pre-determined angle.

23

24 11. Apparatus according to any preceding claim,
25 wherein the at least one member comprises at least
26 one hydrofoil capable of passive rotation about an
27 axis such that each hydrofoil maintains alignment
28 with a periodically reciprocating rectilinear flow.

29

30 12. Apparatus as claimed in any preceding claim,
31 wherein said at least one member is moveable between
32 a first configuration in which it is capable of

WO 2004/022856

PCT/GB2003/003845

27

1 generating positive lift and a second configuration
2 in which it is capable of generating negative lift.

3

4 13. Apparatus according to claim 12, wherein the at
5 least one member has a variable actuating means to
6 vary the positive or negative lift generated by the
7 member.

8

9 14. Apparatus according to claim 12 or 13, wherein
10 the at least one member is rotatable between said
11 first and second configurations about a longitudinal
12 axis thereof.

13

14 15. Apparatus according to any one of claims 12-14,
15 wherein a shaft member is adapted to actuate the at
16 least one member to change it between the first and
17 second configurations.

18

19 16. Apparatus according to any one of claims 10-15
20 further comprising a support framework, where a
21 plurality of shaft members are connected to the
22 framework and on which said at least one member is
23 rotatably coupled.

24

25 17. Apparatus according to claim 16, wherein the at
26 least one member comprises a bearing member by means
27 of which it is coupled to a shaft member connected
28 to the support framework.

29

30 18. Apparatus according to claim 17, wherein the
31 bearing member and shaft member combine to provide a

WO 2004/022856

PCT/GB2003/003845

28

1 rotation enabling portion and a rotation prevention
2 portion.

3

4 19. Apparatus according to claim 18, wherein the
5 rotation prevention portion comprises one or more
6 stop members which are adapted to engage with one or
7 more respective stop members mounted on the
8 respective bearing member.

9

10 20. Apparatus according to claim 19, wherein the
11 bearing member is substantially cylindrical and
12 comprises a pair of stop members which are spaced
13 apart around its inner circumference.

14

15 21. Apparatus according to claim 19 or 20, wherein
16 the shaft member comprises a pair of stop members
17 which are spaced apart around its outer
18 circumference.

19

20 22. Apparatus according to claim 21, wherein one of
21 the bearing stop members is engageable with a
22 respective shaft stop member to define a first
23 negative configuration and the other of the bearing
24 stop members is engageable with the other of the
25 shaft stop members to define a second negative
26 configuration.

27

28 23. Apparatus as claimed in any one of claims 1-8,
29 wherein the at least one member is rigidly connected
30 to a support framework.

31

1 24. Apparatus as claimed in claim 23, wherein the
2 at least one member comprises a disc shaped member
3 which, in use, is adapted to produce positive or
4 negative lift regardless of the direction of flow of
5 fluid thereby.

6
7 25. Energy extracting apparatus for extracting
8 energy from fluid flow, said energy extracting
9 apparatus comprising:

10 a turbine;
11 at least one member, which in use, generates
12 positive or negative lift.

13
14 26. A method of controlling underwater equipment;
15 the method comprising:

16 providing an apparatus having at least one
17 member for generating positive or negative lift;
18 attaching the apparatus to underwater
19 equipment;
20 releasing the apparatus into a fluid;
21 allowing fluid to flow past the at least one
22 member to generate positive or negative lift.

23
24 27. A method as claimed in claim 26, wherein the
25 apparatus is placed in a flow of water.

26
27 28. A method as claimed in claim 26, wherein the
28 underwater equipment is a turbine.

10/526264

WO 2004/022856

PCT/GB2003/003845

1 / 8

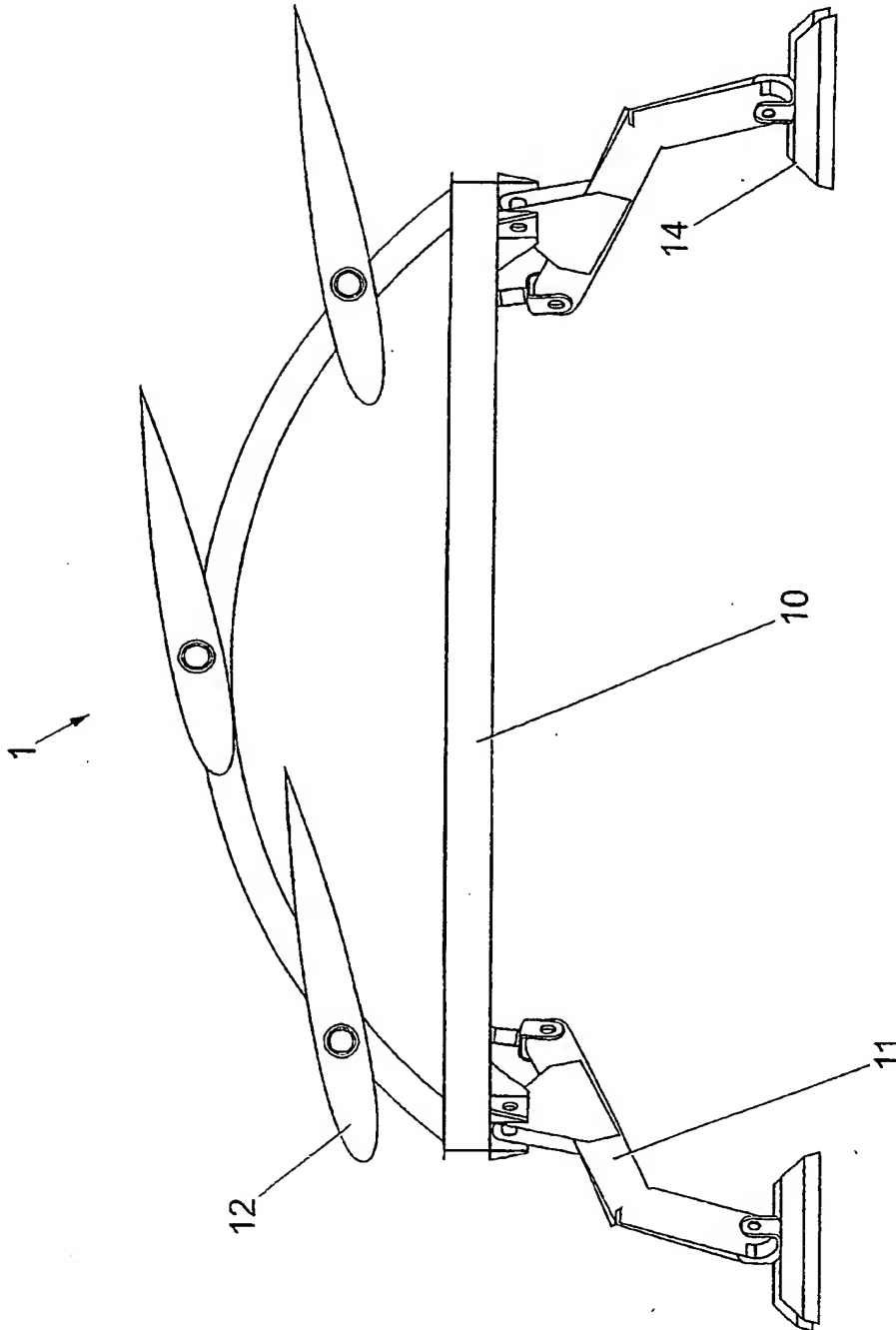


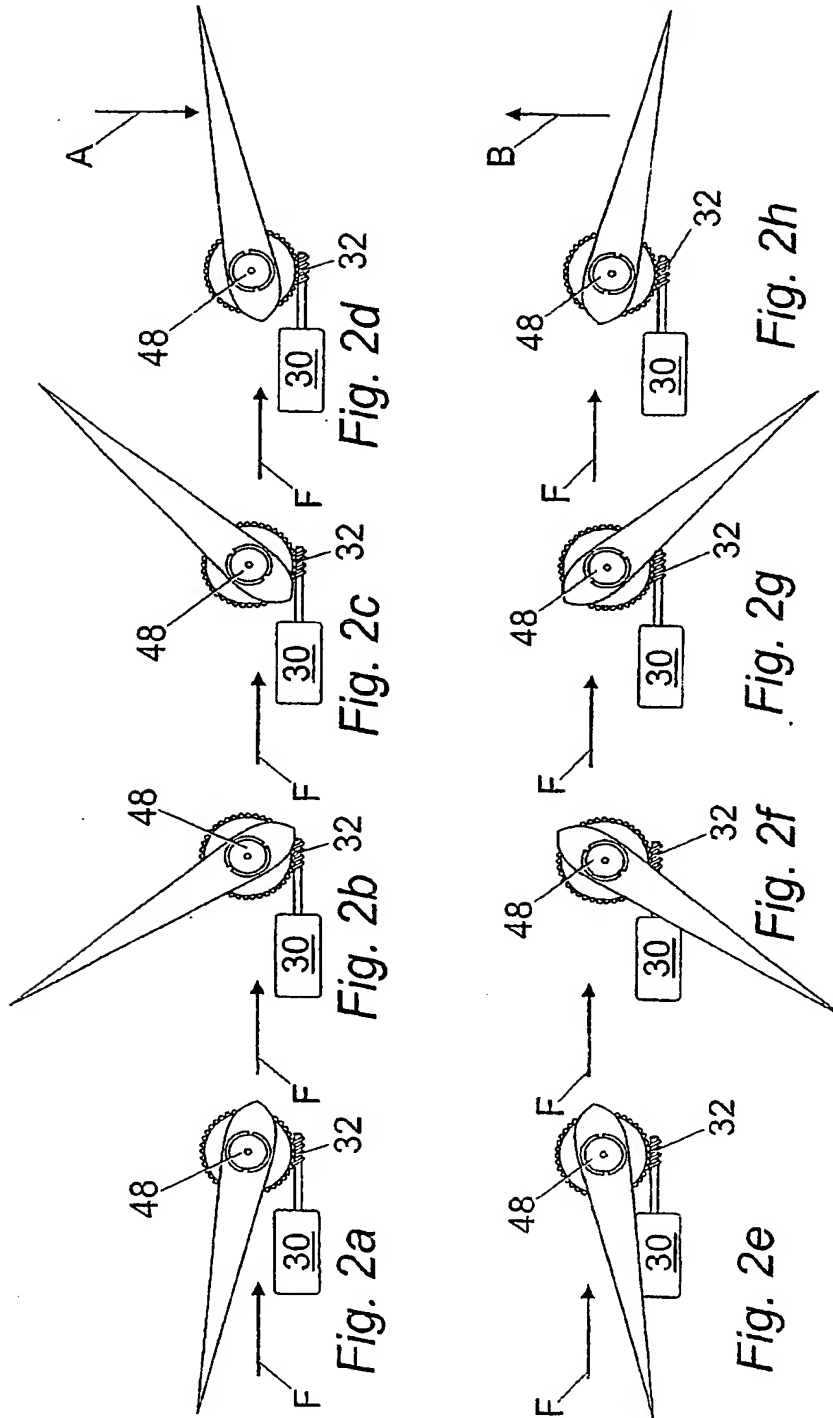
Fig. 1

10/526264

WO 2004/022856

PCT/GB2003/003845

2/8



10/526264

WO 2004/022856

PCT/GB2003/003845

3/8

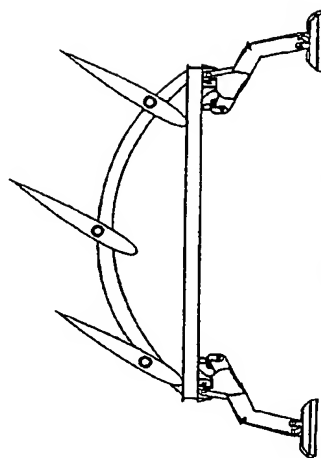


Fig. 2l

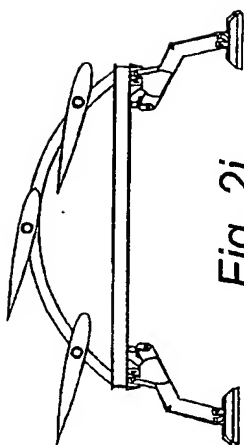


Fig. 2i

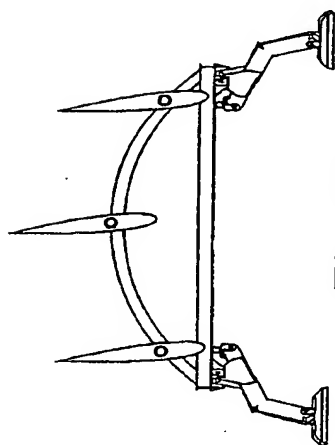


Fig. 2k

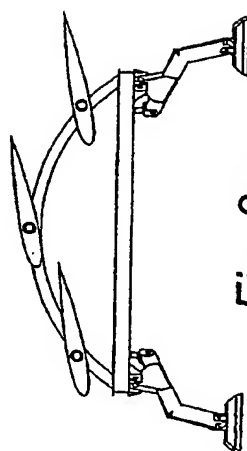


Fig. 2m

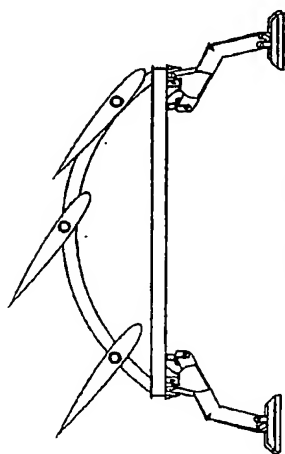


Fig. 2j

10/526264

WO 2004/022856

PCT/GB2003/003845

4 / 8

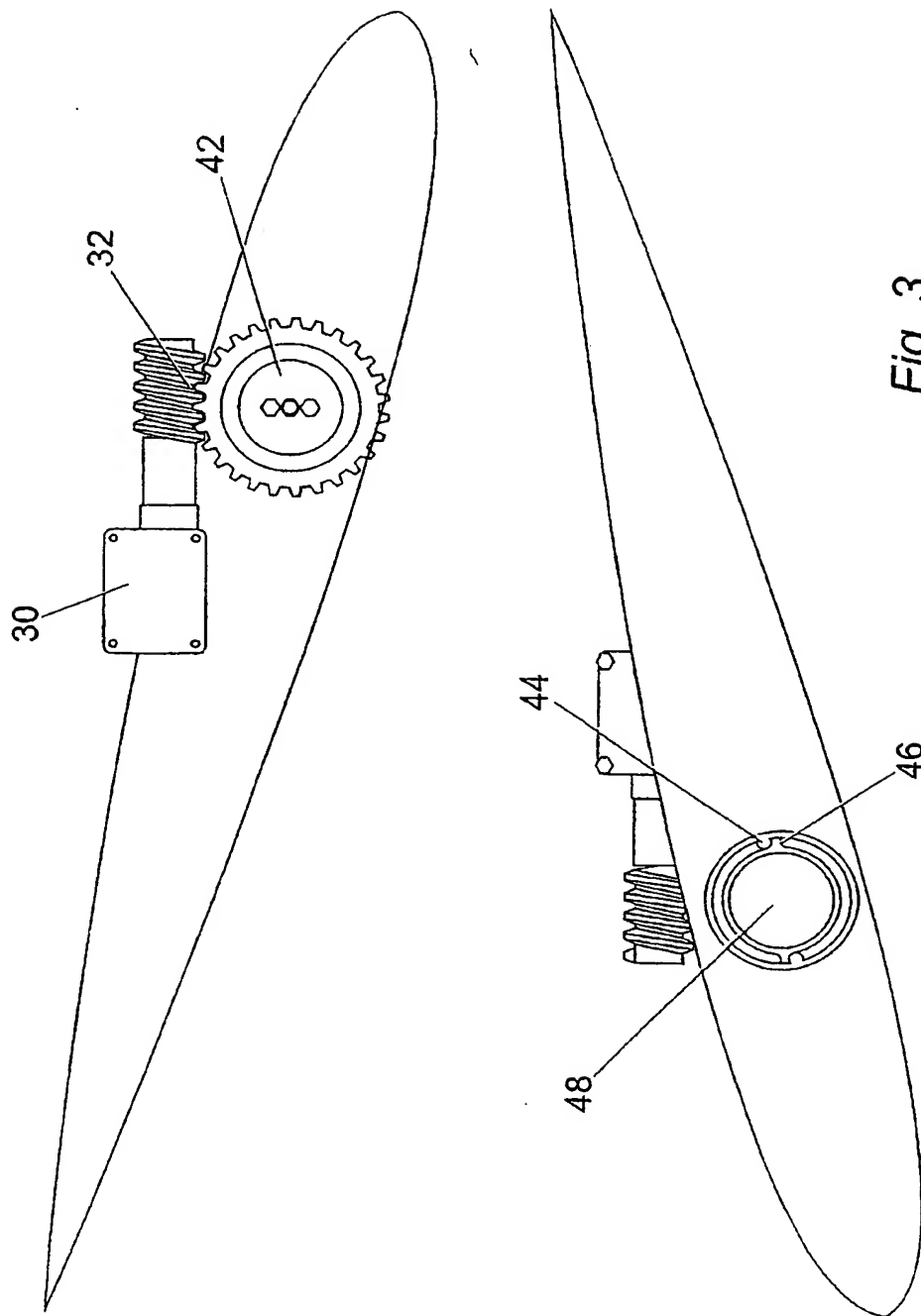


Fig. 3

10/526264

WO 2004/022856

PCT/GB2003/003845

5/8

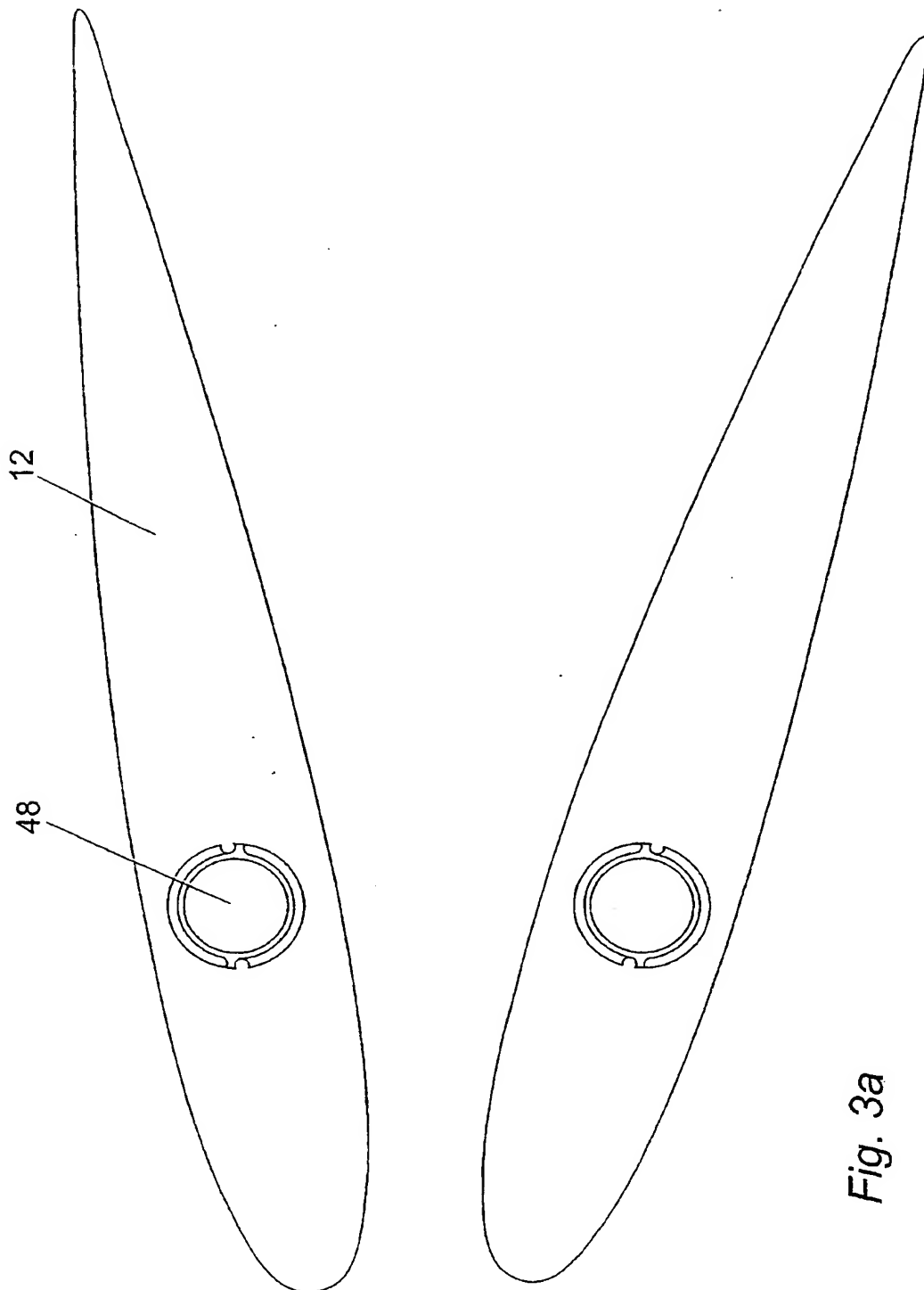


Fig. 3a

10/526264

WO 2004/022856

PCT/GB2003/003845

6 / 8

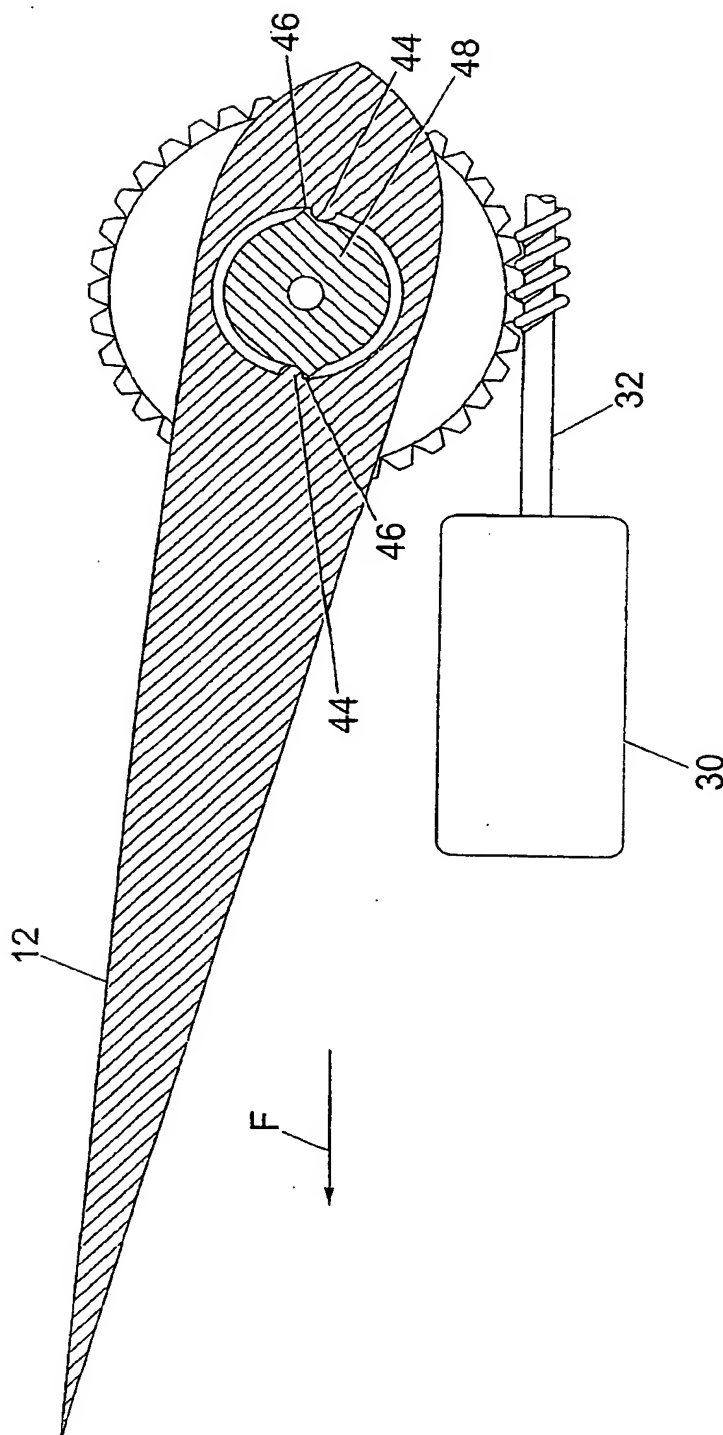


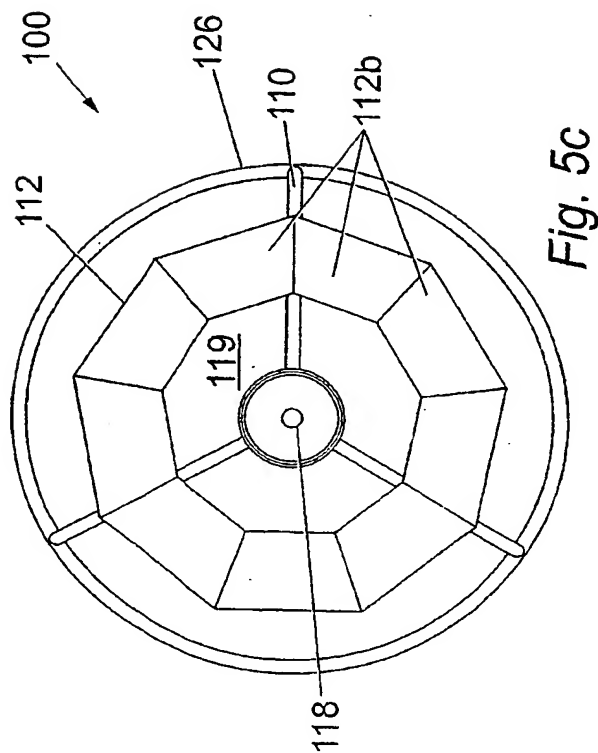
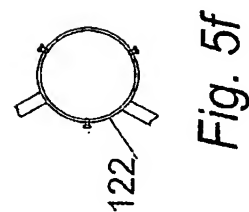
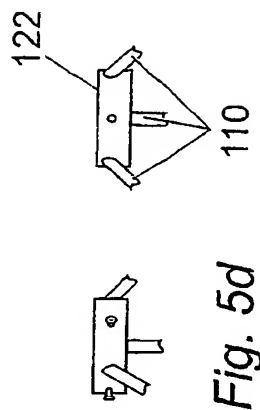
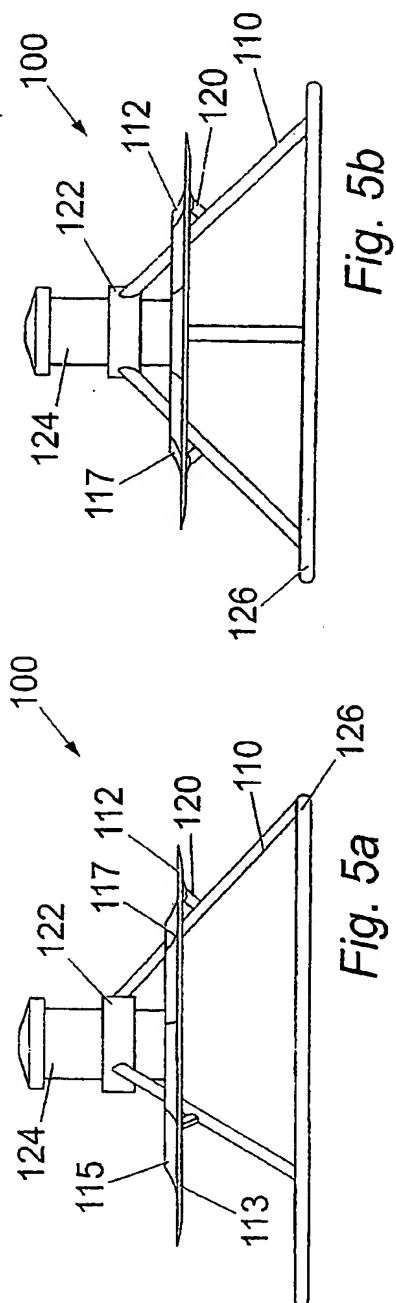
Fig. 3b

10/526264

WO 2004/022856

PCT/GB2003/003845

8 / 8



INTERNATIONAL SEARCH REPORT

 International Classification No
 PCT/66 US/03845

 A. CLASSIFICATION OF SUBJECT MATTER
 IPC 7 E02B9/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 E02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 978 345 A (BAILEY DAVID ZABRISKIE) 31 August 1976 (1976-08-31) column 2, line 12 -column 5, line 23; figures 6,7	1-4, 7-14,23, 25-28
X	DE 199 58 409 A (KIMMIG PETER) 13 June 2001 (2001-06-13) the whole document	1,4-6,9, 12,23,25
P,X	US 2003/072615 A1 (GARICA FELIPE ET AL) 17 April 2003 (2003-04-17) paragraph '0052! - paragraph '0053!; figure 7	1
A	US 4 086 775 A (PETERSON JR CHARLES A) 2 May 1978 (1978-05-02)	

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- *Z* document member of the same patent family

Date of the actual completion of the international search

8 January 2004

Date of mailing of the international search report

19/01/2004

Name and mailing address of the ISA

 European Patent Office, P.B. 5818 Patentlaan 2
 NL - 2280 HV Rijswijk
 Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
 Fax: (+31-70) 340-3016

Authorized officer

Flygare, E

INTERNATIONAL SEARCH REPORT

information on patent family members

International Application No

PCT/Gb US/03845

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 3978345	A	31-08-1976	AU 8139975 A	25-11-1976
			CA 1062584 A1	18-09-1979
			DE 2523030 A1	04-12-1975
			GB 1515561 A	28-06-1978
			JP 1373688 C	07-04-1987
			JP 50155841 A	16-12-1975
			JP 61030154 B	11-07-1986
			NL 7506125 A ,B,	26-11-1975
DE 19958409	A	13-06-2001	DE 19958409 A1	13-06-2001
US 2003072615	A1	17-04-2003	NONE	
US 4086775	A	02-05-1978	NONE	